Appendix B
Loading Conditions and Loading-Condition Classification

B-1. Purpose

The main purposes of Appendix B are to:

- Assemble, for convenience and easy reference, all loading-condition requirements for each structure type as specified in various Engineer Manuals.
- Update the classification of each loading condition to comply with the Table 3-1 definition for *usual*, *unusual,* and *extreme* (U/UN/E).
- Update older guidance to conform with current earthquake and flood loading definitions.
- Provide a U/UN/E loading classification designation for those loading conditions that may fall into either the usual, unusual, or extreme categories depending on the probability of occurrence.

B-2. Loading Conditions, Normal Operating Pool Condition and Coincident Pool Condition

a. General. Although the criteria in this manual is for stability analysis only, the following tables of loading conditions and loading condition classifications are applicable to both the stability evaluation and to the structural design of Corps projects. This is done so the designer can cross-reference between this EM and other guidance. The loading-condition identification number and description identified in this manual, unless otherwise indicated, is the same as that in the structure- specific guidance. Some of the loading conditions will apply to stability evaluation only, some to structural design/evaluation only, and others will apply to both stability and structural design/evaluation. The loading conditions in these tables should be sufficient to cover most situations. However, the structural engineer should closely examine each loading condition to ensure that it is applicable to the particular structure and site conditions, that the assigned classification of usual, unusual, or extreme is correct, and that there are no additional loading conditions which should be investigated. The structural engineer should also consider any unique or special loadings that may occur during construction. Loading condition tables for each structure type are provided below, followed by a description of those loading conditions.

b. Normal operating pool. The normal operating pool condition refers to water surface elevations, which represent maximum loading with a 10-year return period. For flood control projects this will correspond to 10-year maximum inflow conditions. For some navigation projects it may correspond to low flow conditions, which result in 10-year minimum tailwater, coincident with a fairly constant upper pool.

c. Coincident pool. The coincident pool represents temporal average pool conditions, which are used for load combinations that include seismic loads. The pool elevation that is equaled or exceeded 50-percent of the time is the temporal average pool. An estimate of temporal average headwater and tailwater pools can be obtained based on existing project operations data (providing sufficient data exists), or by using inflow data in combination with planned project operating procedures. A plot of this information is shown in Figure B-1. This figure was developed under the assumption the project is operated for a year under mean annual pool conditions, with project inflows varying from month to month due to seasonal variations. The mean monthly pool elevation from Figure B-1 can then be used to develop a pool-duration plot showing the percent of time a particular pool elevation will be equaled or exceeded. The pool elevation that is equaled or exceeded 50-percent of the time (or 182 days per year) is the temporal average pool. This is illustrated by Figure B-2.

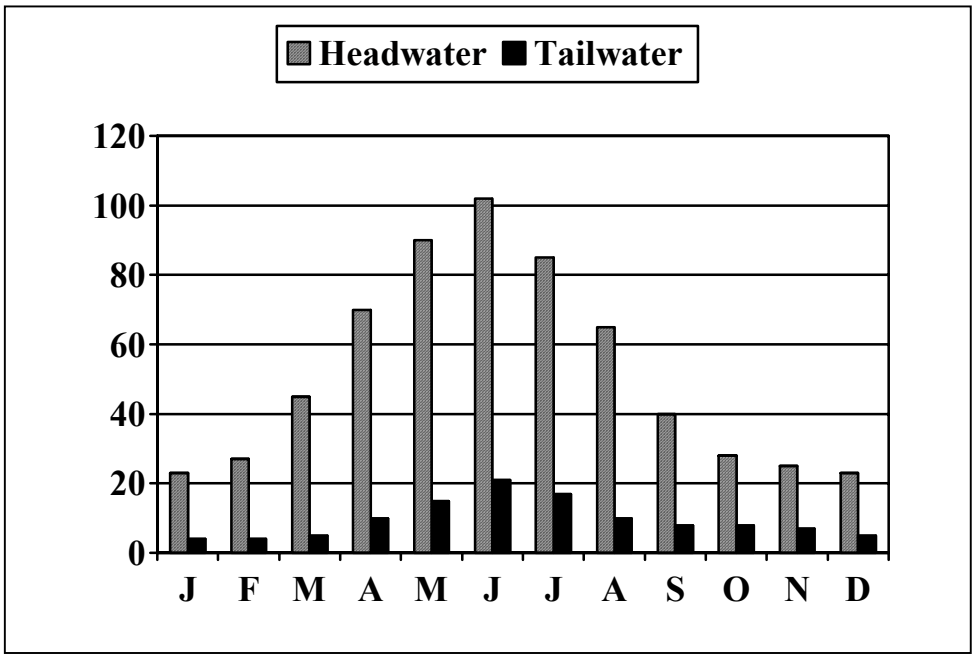

Figure B-1 Monthly Plot of Average Annual Water Levels

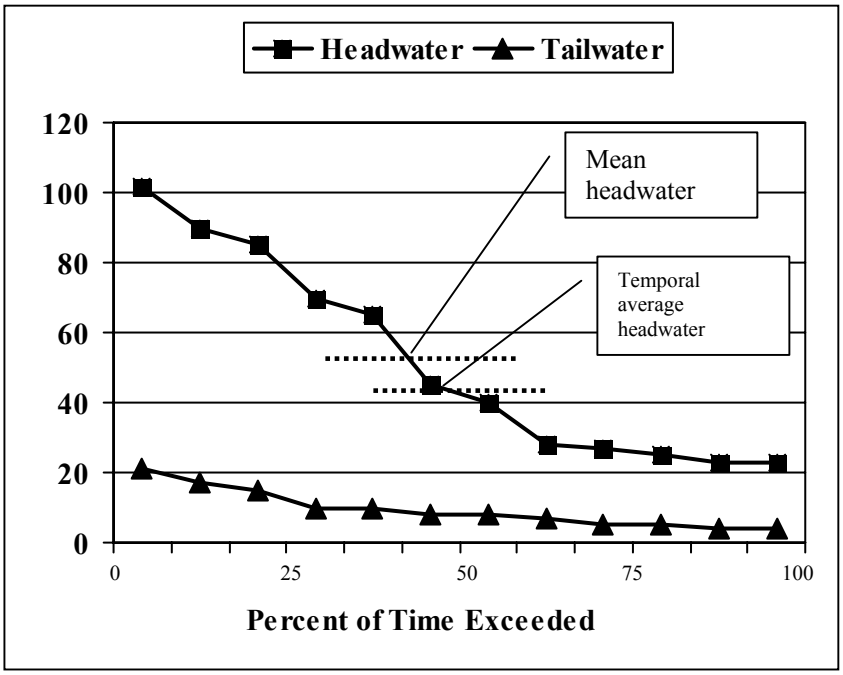

Figure B-2 Percent of Time Average Annual Pools are Equaled or Exceeded

B-3. Classification Tables

Table B-1 Gravity-Dam Loading-Condition Classification
Structure Type: Gravity Dams, EM 1110-2-2200; Navigation Dams, EM 1110-2-2607

Load Case	Loading Description	Classification*
1	Construction Condition	UN
2	Normal Operating	U
3	Infrequent Flood	UN
4	Construction with Operational Basis Earthquake (OBE)	E
5	Coincident Pool with OBE	UN
6	Coincident Pool with Maximum Design Earthquake (MDE)	E
7	Maximum Design Flood (MDF)	U/UN/E

* U = usual, UN = unusual, E = extreme

a. Gravity dam - basic loading conditions. The basic load cases of Table B-1 are generally used in the stability evaluation of concrete gravity dams. These load cases are described below. Load cases used in the stability analysis of powerhouses and power intake sections are covered in Table B-16. For the normal operating load condition, the normal operating pool is defined by Paragraph B-2b(1). For earthquake load conditions, the coincident pool is defined by Paragraph B-2b(2).

(1) Loading condition 1 - Construction.

- Dam structure complete.
- No headwater or tailwater.

(2) Loading condition 2 - Normal Operating.

- Headwater at normal pool as defined by Paragraph B-2b(1)
- Minimum tailwater corresponding with the above headwater.
- Uplift.
- Ice and silt pressure, if applicable.

(3) Loading condition 3 - Infrequent Flood.

- Pool at an elevation representing a flood event with a 300 year return period.
- Minimum corresponding tailwater.
- Uplift.
- Ice and silt pressure, if applicable.

(4) Loading condition 4 - Construction with OBE.

- OBE.
- Horizontal acceleration in upstream direction.
- No headwater or tailwater.

(5) Loading condition 5 - Coincident Pool + OBE.

- OBE, horizontal acceleration in downstream direction.
- Coincident pool condition as defined in Paragraph B-2b(2) with corresponding tailwater.
- Uplift at pre-earthquake level.

- Silt pressure, if applicable.
- No ice pressure.

(6) Loading condition 6 - Coincident Pool + MDE.

- MDE, horizontal acceleration in downstream direction.
- Coincident pool condition as defined in Paragraph B-2b(2) with corresponding tailwater.
- Uplift at pre-earthquake level.
- Silt pressure, if applicable.
- No ice pressure.

(7) Loading condition 7 - MDF.

- Combination of pool and tailwater which produces the worst structural loading condition, with an unlimited return period. (See paragraph 4-2e for additional information on the MDF)
- Uplift.
- Silt, if applicable.
- No ice pressure.

Table B-2 Arch Dam Loading-Condition Classification
Structure Type: Arch Dams, EM 1110-2-2201

Load Case	Loading Description	Classification
SU1	Minimum-usual concrete temperature. Reservoir elevation occurring at that time. Dead Load.	U
SU2	Maximum-usual concrete temperature. Reservoir elevation occurring at that time. Dead Load.	U
SU3	Normal-operating pool condition. Concrete temperature occurring at that time. Dead Load.	U
SUN1	Infrequent Flood. Reservoir at elevation representing a 300 year flood event. Concrete temperature at that time. Dead Load.	UN
SUN2	Minimum-design reservoir elevation. Concrete temperature occurring at that time. Dead Load.	UN
SUN3	End of construction condition. Structure completed, empty reservoir. Temperature Load.	UN
SE1	Reservoir at MDF elevation. Concrete temperature occurring at that time. Dead load.	UN/E
DUN1	OBE plus coincident pool	UN
DUN2	Operating Basis Earthquake (OBE) plus static load case SUN3.	UN
DE1	Maximum Design Earthquake (MDE) plus coincident pool	E

b. Arch dams - basic loading conditions. Table B-2 describes the static and dynamic loading combinations to be used for evaluating sliding stability of arch dam abutments. These loading combinations are also used to evaluate stresses within the dam. The load cases covered in Table B-2 are similar to those in EM 1110-2-2201, and they should be sufficient to cover most arch dams; however, each loading condition should be carefully examined to ensure that it is applicable, and that it is properly classified under one of the three categories, i. e., usual, unusual, or extreme. The loading combinations should be established at the earliest stages of design and adhered to throughout

the development of the final design. Since there are different factors of safety for different loading conditions, the selection and classification of the load cases greatly influence the geometry of an arch dam and the resulting stresses The structural engineer evaluating stability should refer to paragraph B-2b for the definition of Anormal operating@ and Acoincident@ pool conditions, and should refer to paragraphs 4-2 c and 4-2 e for the definitions of Infrequent Flood (IF) and Maximum Design Flood (MDF).

Table B-3 Retaining-Wall Loading-Condition Classification
Structure Type: Retaining Walls, EM 1110-2-2502

Load Case	Loading Description	Classification
R1	Normal Operating	U
R2	Normal Operating + Short Duration Loads	UN
R3a	Normal Operating + OBE	UN
R3b	Normal Operating + MDE	E

Table B-4 Inland Flood-Wall Loading-Condition Classification
Structure Type: Inland Flood Walls, EM 1110-2-2502

Load Case	Loading Description	Classification
I1	Infrequent Flood	UN
I2	MDF	UN/E
I3a	Coincident Pool + OBE	UN
I3b	Coincident Pool + MCE	E
I4	Construction	UN

Table B-5 Coastal Flood-Wall Loading-Condition Classification
Structure Type: Coastal Flood Wall, EM 1110-2-2502

Load Case	Loading Description	Classification
C1	Surge Stillwater + Coincident Wave	UN/E
C2a	Coincident Pool + OBE	UN
C2b	Coincident Pool + MDE	E
C3	Construction	UN
C4	Normal Operating	UN

c. Walls - basic loading conditions. Loading conditions for the various types of walls are summarized in Tables B-3 through B-5. These loading conditions are generally representative of conditions affecting retaining walls, inland flood walls, and coastal flood walls. The loading conditions in the tables are described in further detail in the following paragraphs. Note that some walls may require consideration of loadings from more than one of the above tables in cases where the wall will act as a retaining wall for one loading condition, and as a flood wall for another loading condition.

(1) Retaining walls.

(a) Loading Condition R1 - Normal Operating.

- Backfill is placed to the final elevation (the backfill is dry, moist, or partially saturated as the case may be).

- Surcharge loading, if present, is applied (stability should be checked with and without surcharge).
- Any existing lateral and uplift pressures due to water are applied.
- Construction loads, which are not considered short-duration loads.

(b) Loading Condition R2 - Normal Operating + Short Duration Loads. This case is the same as R1 except the water table level in the backfill rises, for a short duration, or another type of loading of short duration is applied.

(c) Loading Condition R3a - Normal Operating + OBE. This is the same as Case R1 except with the addition of OBE induced lateral and vertical loads. The uplift is the same as for Case R1.

(d) Loading Condition R3b - Normal Operating + MDE. This is the same as Case R1 except with the addition of Maximum Design Earthquake (MDE) induced lateral and vertical loads. The uplift is the same as for Case R1.

(2) Inland floodwalls.

(a) Loading Condition I1 - Infrequent Flood.

- Backfill in place to final elevation.
- Water at an elevation representing a flood with a 300-year return period (To be investigated only when the MDF is an extreme load condition). See paragraphs 4-2c and 4-2e for information regarding the IF and MDF.
- Uplift.

(b) Loading Condition I2 - MDF.

- Combination of water on the protected and unprotected side, which produces the worst structural loading condition, with an unlimited return period.
- Uplift.

(c) Loading Condition I3a - Coincident Pool + OBE. (Note: This load case need only be considered if the wall has a significant loading during the non-flood stage)

- Backfill in place to final elevation.
- Water, if applicable, is at an elevation that is coincident with mean annual non-flood operating conditions.
- Uplift, if applicable.
- OBE-induced lateral and vertical loads.

(d) Loading Condition I3b +MDE - Coincident Pool + MDE. (Note: This load case need only be considered if the wall has a significant loading during the non-flood stage)

- Backfill in place to final elevation.
- Water, if applicable, is at an elevation that is coincident with mean annual non-flood operating conditions.
- Uplift, if applicable.
- MDE-induced lateral and vertical loads.

(e) Loading Condition I4 - Construction Condition.

- Floodwall is in place with the loads added which are possible during the construction period but are of short duration.

(3) Coastal flood walls.

(a). Loading Condition C1 - Design Surge Stillwater + Design Coincident Wave.

- Design surge stillwater condition + the governing nonbreaking, breaking, or broken wave conditions coincident with the design surge stillwater condition.
- Uplift is acting, based on the surge stillwater.

(b) Loading Condition C2a - Coincident Pool+ OBE.

- Water at level representing mean annual tide pool conditions
- Uplift, if applicable, is acting.
- OBE induced lateral and vertical loads, if applicable, are acting.

(c) Loading Condition C2b - Coincident Pool + MDE.

- Same as condition C2a, except use MDE.

(d) Loading Condition C3 - Construction.

- Floodwall is in place with the loads added which are possible during the construction period but are of short duration.

(e) Loading Condition C4 - Normal Operating

- Water is at the highest level with a 10-year return period on the unprotected side.
- Uplift is acting

Table B-6 Intake Tower Loading-Condition Classification
Structure Type: Intake Towers, EM 1110-2-2400

Load Case	Loading Description	Classification*
U1	Normal Pool, All Gates Open	U
U2	Normal Pool, One or more Gates Closed	U
U3	Normal Pool, All Gates Closed	U
U4	Normal Pool with Silt	U
U5	Minimum Pool	U
UN1	Infrequent Flood, All Gates Open	UN
UN2	Infrequent Flood, One or more Gates Closed	UN
UN3	Infrequent Flood, All Gates Closed	UN
UN4	Construction	UN
UN5	Diversion	UN
UN7	Maintenance Bulkheads in Place	UN
UN8	OBE + Coincident Pool	UN
E1	MDE + Coincident Pool	E
E2	MDF	UN/E

d. Intake towers - basic loading conditions. Specific operational and site conditions from construction throug project life and structure configuration may require that the stability loading conditions be modified, or that additional analysis of conditions be made. The loading conditions of Table B-6 are described below.

(a) Loading Condition U1 - Normal Pool, All Gates Open.

- Dead load of structure.
- Reservoir at normal pool as defined by Paragraph B-2b(1).
- Earth load (if any).
- Ice loads, if applicable.
- Uplift.
- Water surface inside structure drawn down to hydraulic gradient with all gates fully opened.
- Wave loads, if applicable.

(b) Loading Condition Case No.U2 - Normal Pool, One or More Gates Closed.

- Dead load of structure.
- Reservoir at normal pool as defined by Paragraph B-2b(1).
- One or more gates closed with other gates fully opened and water surface drawn down to hydraulic gradient in remainder of structure in combinations that produce the most unstable conditions.
- Earth load (if any).
- Ice loads, if applicable.
- Uplift.
- Wet-well full of water upstream from closed gate.
- Wave loads, if applicable.

(c) Loading Condition U3 - Normal Pool, All Gates Closed.

- Dead load of structure.
- Reservoir at normal pool as defined by Paragraph B-2b(1).
- Earth load (if any).
- Uplift.
- Wave loads, if applicable.

(d) Loading Condition U4 - Normal Pool with Silt.

- Reservoir with silt for the most critical of preceding conditions U1 through U3.

(e) Loading Condition U5 - Minimum Pool.

- Reservoir empty or at minimum pool.
- Dead load of structure.
- Earth load (if any).
- Ice loads, if applicable.
- Wind load in the direction that would produce the most severe foundation pressures.
- Uplift.
- Wave loads, if applicable.

(f) Loading Conditions UN1 through UN3.

- Loading conditions UN1 through UN3 are the same as U1 through U3 except the reservoir, rather than at the normal pool condition, is at the infrequent flood stage meaning at an elevation representing a flood event with a 300-year return period.

(g) Loading Condition UN4 - Construction.

- Reservoir empty.
- Dead load of structure (partially or fully completed).
- Earth load (if any).
- Heavy construction equipment required on or near the structure during construction.
- Wind load in the direction that would produce the most severe foundation pressures.

(h) Loading Condition UN5 - Diversion.

- Reservoir at maximum elevation expected during diversion.
- Dead load of structure at diversion level completion.
- Earth load (if any).
- Heavy construction equipment required on or near the structure.

Wind load in the direction that would produce the most severe foundation pressures.

(i) Loading Condition UN7 - Maintenance Bulkheads in Place.

- Bulkheads in place, no water in structure downstream of bulkheads.
- Dead load of structure.
- Reservoir at maximum pool level at which bulkheads are used.
- Earth loads (if any).
- Uplift.

(j) Loading Condition UN8 - Coincident Pool + OBE.

- OBE for the most critical of the conditions U1 through U5 with the reservoir at the coincident pool elevation.
- No ice.

(k) Loading Condition E1 - Coincident Pool + MDE.

- MDE for the most critical of the conditions U1 through U5 with the reservoir at the coincident pool elevation.
- No ice.

(l) Loading Condition E2 - MDF.

- Pool at PMF elevation.
- All gates opened or closed, depending on project operating criteria.

Table B-7 Navigation Lock Loading-Condition Classification
Structure Type: Navigation Lock Walls, EM 1110-2-2602

Load Case	Loading Description	Classification
1A	Normal Operating Lower Pool in Landward Lock Chamber (Upper Pool in Riverward Lock Chamber)(1)	U
1B	Normal Operating Upper Pool in Landward Lock Chamber (Lower Pool in Riverward Lock Chamber)(1)	U
2A	Unusual Operating Same as 1A or 1B with Extreme Low Water	UN
2B	Maintenance Condition	UN
2C	1A and 1B with OBE	UN
2D	1A and 1B with MDE	E
3	Construction Condition	UN

Note (1): Normal operating loading conditions in parentheses apply only if the lock has two adjacent chambers.

Table B-8 Navigation Lock Loading-Condition Classification
Structure Type: Navigation Lock – Upper and Lower Gate Bays, EM 1110-2-2602

Load Case	Loading Description	Classification
1A	Normal Operating, Gates Loaded	U
1B	Normal Operating, Gates Unloaded	U
2B	1A or 1B with Extreme Low Water	UN
2C & 2D	1A & 1B with Ineffective Drains	UN
2E	Maintenance Condition	UN
2A & 2F	1A & 1B with OBE	UN
2G & 2H	1A and 1B with MDE	E
3	Construction Condition	UN

Table B-9 Navigation Lock Loading-Condition Classification
Structure Type: Navigation Lock – Approach Walls, EM 1110-2-2602

Load Case	Loading Description	Classification
1A	Normal Operating + Barge Impact (T_r = 10 years)	U
1B	Normal Operating + Barge Impact (T_r = 300 years)	UN
1C	Normal Operating + Barge Impact (T_r = 1000 years)	E
2A	Normal Operating + OBE	UN
2B	Normal Operating + MCE	E
3	Construction Condition	UN

Table B-10 Navigation Lock Loading-Condition Classification
Structure Type: Navigation Lock – Upper and Lower Sills, EM 1110-2-2602

Load Case	Loading Description	Classification
1A	Normal Operating	U
2A	1A with Extreme Low Tailwater	UN
2B	Maintenance Condition	UN

e. Navigation locks - basic loading conditions. Navigation locks may have land walls, river walls, intermediate walls, upper- and lower-gate bays, upper- and lower-approach walls , and upper- and lower-sill structures (Tables B-7 through B-10). Different operating and flood- discharge conditions can result in maximum head differentials and uplift pressures for each of these structures. Maintenance conditions, where the lock chambers and filling systems are unwatered , can sometimes govern the design. Loss of pool and rapid drawdown conditions, if possible, must also be evaluated. The effectiveness of drains used to reduce the water table in backfill materials and in the foundation must be considered in the stability analyses. Hawser and barge impact loads must be considered in the stability of navigation lock structures. Hawser and barge impact loads when combined with other normal-operating-condition loads are considered to be an unusual load condition. After the amount and intensity of the individual loads acting on the lock walls or monoliths have been determined as separate considerations, the possible combinations of such loads must be examined to determine the most adverse condition. Loadings that will ordinarily require examination are described in the following paragraphs. However, independent checks of each structure under consideration should be made to determine whether these conditions are adequate for determination of the most critical loading.

(1) Lock chamber walls (including land wall, river wall, and intermediate wall)

(a) Loading Condition 1A - Normal Operating Condition.

- Backfill loads (soil, water, and surcharge).
- Hawser load.
- Lower pool in landward lock chamber, upper pool in riverward lock chamber.
- Uplift as defined by water elevations.
- Vessel impact (Mean annual impact force).

(b) Loading Condition 1B - Normal Operating Condition.

- Loads (soil, water, and surcharge). Backfill.
- Hawser load.
- Upper pool in landward lock chamber, lower pool in riverward lock chamber.
- Uplift as defined by water elevations.
- Vessel impact

(c) Loading Condition 2A - Operating Condition With Drawdown. The same requirements for Conditions 1A and 1B are included except for the following conditions.

- Extreme low water stage for lower pool.

(d) Loading Condition 2B - Maintenance Condition. The same requirements for Conditions 1A and 1B are included except for the following conditions.

- Lock chamber unwatered to a predetermined level.
- No hawser load.

(e) Loading Condition 2C - Normal Operating +OBE. The same requirements for Conditions 1A and 1B except for the condition of an OBE earthquake load added in the most critical direction.

(f) Loading Condition 2D - Normal Operating + MDE. The same requirements for Conditions 1A and 1B except for the condition of an MDE earthquake load added in the most critical direction.

(g) Loading Condition 3 - Construction Conditions.

- Backfill loads (soil and surcharge).
- Wind as applicable.
- No uplift.
- Hydrostatic forces are active in accordance with construction or cofferdam plans.

(2) Upper and lower gate bays.

(a) Loading Condition 1A - Normal Operating Condition.

- Upper pool upstream of gates.
- Lower pool downstream of gates.
- Applicable wall loadings.

(b) Loading Condition 1B - Normal Operating Condition.

- Gates closed.
- For upper gate bay, upper pool in gate bay.
- For lower gate bay, lower pool in lock chamber.
- Applicable wall loadings.

(c) Loading Condition 2B - Operating Conditions with Extreme Low Water. The same requirements for conditions 1A and 1B except for the following conditions.

- Pools in lock chamber or lock entrance, with extreme low tailwater stages.
- Uplift as defined by water elevations.

(d) Loading Condition Case No=s. 2C and 2D - Operating Drains Ineffective Condition. The same requirements for Conditions 1A and 1B are included except for the condition of the raised saturation level caused by ineffective drains or ponding.

(e) Loading Condition 2E - Maintenance Condition. The same requirements as for Condition 1B except for the following conditions.

- Lock chamber unwatered to a predetermined level.
- Uplift as defined by water elevations.

(f) Loading Condition Case No=s. 2F and 2A- Normal Operating +OBE. The same requirements for Conditions 1A and 1B except for the condition of the OBE loads added in the most critical direction.

(g) Loading Condition Case No=s. 2G and 2H- Normal Operating + MDE. The same requirements for Cases 1A and 1B except for the condition of the MDE loads added in the most critical direction.

(h) Loading Condition 3A - Construction Conditions.

- Moist backfill to a predetermined level.
- Permanent or construction surcharge.
- Wind as applicable.
- No uplift.
- Gates swinging freely in appropriate mitered position.
- Hydrostatic forces are active in accordance with construction or cofferdam plans.

(3) Upper and lower approach walls.

(a) Loading Condition 1A - Usual Barge-Impact Loading.

- Water and backfill loads.
- Barge impact (Maximum mean impact force with a return period of 10 years) on face of wall at most critical angle of incidence.
- Uplift as defined by water elevations.

(b) Loading Condition 1B - Unusual Barge-Impact Loading. The same requirements as Condition 1A except the barge impact is a force representing the mean maximum force with a return period of 300 years.

(c) Loading Condition Case 1C - Extreme Barge-Impact Loading. The same requirements as Condition 1A except the barge impact is a force representing the mean maximum force with a return period of 1,000 years.

(d) Loading Condition 2A - Normal Operating + OBE.

- Most critical normal operating condition.
- OBE loads in the most critical direction.
- No impact or hawser pull .

(e) Loading Condition 2B - Normal Operating + MDE.

Most critical normal operating condition.

- MDE loads in the most critical direction.
- No impact or hawser pull .

(f) Loading Condition 3 - Construction Conditions.

- Moist backfill.
- Permanent or construction surcharge.
- Wind as applicable.
- No uplift.

(4) Upper and lower sills.

(a) Loading Condition 1 - Normal Operating Condition.

- Upper pool upstream of gate.
- Lower pool downstream of gate.
- Fill or silt to top of sill on upstream side.
- Applicable gate loads for vertically framed miter gates and rolling gates.
- Uplift and vertical water loading as defined by water elevations.

(b) Loading Condition 2A - Operating Condition with Extreme Low Tailwater. The same requirements for Case 1 are included except for the following conditions.

- Extreme low-water stage.

(c) Loading Condition 2B - Maintenance Condition.

- Upper pool upstream of temporary closure structure.
- Lock chamber unwatered.
- Uplift and vertical water loading as defined by water elevations.

Table B-11 Spillway Loading-Condition Classification
Structure Type: Spillway – Approach Channel Walls EM 1110-2-2400

Load Case	Loading Description	Classification
I	Channel Empty	U
II	Partial Sudden Drawdown, PMF	E
III	Sudden Pool Rise, PMF	E
IVA	Coincident Pool + OBE	UN
IVB	Coincident Pool + MDE	E

Table B-12 Spillway Loading-Condition Classification
Structure Type: Spillway – Chute Walls EM 1110-2-2400

Load Case	Loading Description	Classification
I	Channel Empty	U
II	Water in Channel, PMF	E
IIIA	Coincident Pool + OBE	UN
IIIB	Coincident Pool + MDE	E

Table B-13 Spillway Loading-Condition Classification
Structure Type: Spillway – Basin Walls EM 1110-2-2400

Load Case	Loading Description	Classification
I	Construction or Maintenance	UN
II	Rapid Closure of Gates	UN
III	MDF Discharge Conditions	U/UN/E
IVA	Coincident Pool + OBE	UN
IVB	Coincident Pool + MDE	E

Table B-14 Spillway Loading-Condition Classification
Structure Type: Spillway – Stilling Basin Floor EM 1110-2-2400

Load Case	Loading Description	Classification
I	MDF Discharge	U/UN/E
II	Rapid Closure of Gates	UN/E

Table B-15 Spillway Loading-Condition Classification
Structure Type: Spillway – Weir EM 1110-2-2400

Load Case	Loading Description	Classification
	Per Gravity Dam Requirements EM 1110-2-2200	

f. Spillways - basic loading conditions. Stability analyses for overflow sections of gravity and arch dams, and for spillways of embankment dams must not only investigate the maximum differential head conditions described for nonoverflow sections, (spillway gates closed), but also the maximum differential head and uplift conditions that can occur during spill (gates open). The spillway weir, chute walls, apron, and stilling basin all have different conditions that can cause maximum differential head, and maximum uplift. Conditions and combinations of loadings that will ordinarily require examination are described in the following paragraphs for each of the various types of structures common to spillways (Tables B11-15).

(1) Approach channel walls.

(a) Loading Condition I - Channel Empty, Pervious Drained Backfill Conditions.

- Channel empty.
- Backfill submerged to elevation of line of drains, and naturally drained above this elevation. Surcharge loading on backfill, if applicable.
- Uplift defined by water elevations.

(b) Loading Condition II - Partial Sudden Drawdown, Impervious Backfill Conditions.

- Partial sudden drawdown of reservoir from PMF elevation.
- Water in channel to drawdown elevation, which may occur suddenly.
- Fill submerged to profile reached during PMF, drained above.
- Uplift defined by water elevations.

(c) Loading Condition III - Sudden Rise of Reservoir, Impervious Backfill Conditions.

- Sudden rise of reservoir to PMF elevation.
- Water in channel to PMF conditions.
- Fill submerged to concurrent water surface in fill, naturally drained above.
- Water above fill to PMF elevation.
- Uplift defined by water elevations.

(d) Loading Condition IVA - Coincident Pool + OBE.

- Coincident pool elevation as defined in Paragraph B-2b(2).
- Backfill to predetermined height.
- Surcharge loading, if applicable.
- Uplift defined by water elevations.
- OBE loads in most critical direction.

(e) Loading Condition IVB - Coincident Pool + MDE. The same requirements as for Condition IVA except the MDE is used instead of the OBE.

(2) Spillway chute walls.

(a) Loading Condition I - Channel Empty, Pervious Drained Backfill Conditions.

- Channel empty.
- Backfill submerged to elevation of drains.
- Backfill naturally drained above elevation of drains.
- Surcharge loading on backfill, if applicable.
- Uplift defined by water elevations.

(b) Loading Condition II - Water in Channel to PMF Elevation.

- Water in channel to PMF conditions.
- Backfill submerged to elevation of drains.
- Backfill naturally drained above drains.
- Surcharge loading on backfill, if applicable.
- Uplift defined by water elevations.

(c) Loading Condition IIIA --Coincident Pool + OBE.

- Coincident pool elevation as defined in Paragraph B-2b(2).
- Backfill to predetermined height.
- Surcharge loading, if applicable.
- Uplift defined by water elevations.
- OBE loads in most critical direction.

(d) Loading Condition IIIB - Coincident Pool + MDE. The same requirements as for Case IIIA except the MDE is used instead of the OBE.

(3) Stilling basin walls.

(a) Loading Condition 1- Construction or Maintenance Condition.

- Stilling basin empty.
- Backfill submerged to drain or higher if, during construction or maintenance, higher elevation is anticipated with stilling basin unwatered.
- Backfill above drain naturally drained.
- Surcharge, if applicable.
- Uplift defined by water elevations.

(b) Loading Condition II - Rapid Closure of Gates or Reduction of Discharge of Ungated Spillway.

- Maximum reduction of discharge and tailwater which is expected to occur rapidly.
- Water surface inside stilling basin at tailwater corresponding to reduced flow conditions.
- Backfill submerged to elevation midway between tailwater before and after reduction (corresponding to 50-percent reduction by drainage).
- Backfill above level of submergence naturally drained.
- Uplift of uniform intensity across the base with pressure equal to reduced hydrostatic head in backfill.

(c) Loading Condition III - MDF Operating Conditions, Pervious Backfill.

- Water surface inside at hydraulic jump profile for MDF discharge condition. This condition creates the greatest differential head between outside and inside faces of the wall.
- Backfill submerged to the MDF tailwater conditions.

- Backfill above tailwater is naturally drained.
- Uplift across base varying uniformly from tailwater at heel to value midway between tailwater and jump profile at toe (the latter corresponds to 50-percent relief of unbalanced pressure by floor drainage).

(d) Loading Condition IVA - Coincident Pool + OBE.

- Coincident pool elevations as defined by Paragraph B-2b(2).
- Backfill to predetermined height.
- Surcharge loading, if applicable.
- Uplift defined by water elevations.
- OBE loads in most critical direction.

(e) Loading Condition IVB - Coincident Pool + MDE. The same requirements as for Condition IVA except the MDE is used instead of the OBE.

(4) Stilling basin floor.

(a) Loading Condition I - Stilling Basin Operating During MDF.

- MDF condition creating greatest differential pressure between bottom and top surfaces of the basin floor.
- Water surface over slab at hydraulic jump profile.
- Hydrostatic pressure under slab to elevation of full tailwater depth.

(b) Loading Condition II - Rapid Closure of Gates or Reduction of Discharge of Ungated Spillway.

- Maximum probable reduction of discharge and tailwater inside stilling basin due to gate closure.
- Water surface inside stilling basin at tailwater corresponding to reduced flow conditions.
- Uplift of uniform intensity with pressure equal to hydrostatic head midway between tailwater before and after reduction (corresponding to 50-percent reduction by drainage).

Table B-16 Power Plant Loading-Condition Classification
Structure Type: Power Plant Structures EM 1110-2-3001

Load Case	Loading Description	Classification
S or M-1A	Normal Operating Condition	U
S or M-1B	Flood-Control Pool Condition	UN/E
S or M-2	Powerhouse Flooding Condition	UN/E
S or M-3	Draft Tube Flood Condition	UN/E
S or M-4	Construction Condition	UN
S or M-5A	Coincident Pool + OBE	UN
S or M-5B	Coincident Pool + MDE	E

g. Power plant structures - basic loading conditions. Powerhouses may either be part of a dam or may be located separate from the dam. In either condition, stability analyses must consider the maximum differential head and uplift conditions that occur with the gates closed and the water passages empty, as well as those that can occur with the gates open and the water passages full. A stability analysis should be made for each monolith of the powerhouse, and all critical levels should be investigated for the most severe combinations of horizontal and vertical forces. In the condition of a monolith in which the power unit will not be installed with the initial construction, the stability analysis should be investigated for the interim as well as the final condition. Analysis should be made for the applicable conditions indicated below and for any other combinations of conditions, which might prove critical.

Conditions S-1A, S-1B, S-2, S-3, S-4, S-5A, and S-5B are applicable when the powerhouse is separated from the dam, and Conditions M-1A, M-1B, M-2, M-3, M-4, M-5A, and M-5B are applicable when the powerhouse and headworks form a part of the dam (Table B-16).

(1) Powerhouse separated from the dam.

(a) Loading Condition S-1A - Normal Operating Condition.

- Head gates open, headwater at normal operating pool level as defined by Paragraph B-2b(1).
- Hydraulic thrusts.
- Minimum tailwater.
- Spiral case full.
- Draft tube full.
- Uplift.

(b) Loading Condition S-1B - Flood-Control Pool Operating Condition.

- Head gates open, headwater at flood-control pool elevation.
- Hydraulic thrusts.
- Minimum tailwater.
- Spiral case full.
- Draft tube full.
- Uplift .

(c) Loading Condition S-2 - Powerhouse Flooding Condition.

- Head gates open.
- Tailwater at powerhouse flooding level.
- Spiral case full.
- Draft tube full.
- Uplift.

(d) Loading Condition S-3 - Draft Tube Flooding Condition.

- Head gates closed.
- Tailwater at draft-tube flooding level.
- Spiral case empty.
- Draft tube empty.
- Uplift.

(e) Loading Condition S-4 - Construction Condition.

- No tailwater.
- No uplift .

(f) Loading Condition S-5A - Coincident Pool Condition + OBE.

- Head gates open, headwater at coincident pool elevation as defined by Paragraph B-2b(2).
- Hydraulic thrusts.
- Minimum tailwater.
- Spiral case full.
- Draft tube full.
- Uplift.
- OBE loads acting in most critical direction.

(g) Loading Condition S-5B - Coincident Pool Condition + MDE.

- The same requirements for S-5A except for the condition of an MDE, rather than OBE, acting in the most critical direction.

(2) Powerhouse part of the dam.

(a) Loading Condition M-1A - Normal Operating Condition.

- Head gates closed, headwater at normal operating pool level as defined by Paragraph B-2b(1).
- Minimum tailwater.
- Spiral case open to tailwater.
- Draft tube open to tailwater.
- Uplift.

(b) Loading Condition M-1B - Flood-Control Pool Operating Condition.

- Head gates open, headwater at flood-control pool elevation.
- Minimum tailwater.
- Spiral case open to tailwater.
- Draft tube open to tailwater.
- Uplift .

(c) Loading Condition M-2 - Powerhouse Flooding Condition.

- Head gates open.
- Headwater at maximum flood level.
- Tailwater at powerhouse flooding level.
- Spiral case full.
- Draft tube full.
- Uplift.

(d) Loading Condition M-3 - Draft Tube Flooding Condition.

- Head gates closed.
- Headwater at top of flood-control pool.
- Tailwater at draft-tube flooding level.
- Spiral case empty.
- Draft tube empty.
- Uplift.

(e) Loading Condition M-4 - Construction Condition.

- No uplift.

(f) Loading Condition M-5A - Coincident Pool Condition + OBE.

- Head gates closed, headwater at coincident pool elevation as defined by Paragraph B-2b(2).
- Minimum tailwater.
- Spiral case open to tailwater.
- Draft tube open to tailwater.
- Uplift .
- OBE loads acting in most critical direction.

(g) Loading Condition M-5B - Coincident Pool Condition + MDE. The same requirements for M-5A except for the condition of an MDE , rather than OBE, acting in the most critical direction.

Table B-17 Pumping Station Loading-Condition Classification
Structure Type: Pumping Stations, EM 1110-2-3104

Load Case	Loading Description	Classification
4-4a	Construction Condition	UN
4-4b	Normal Operating Condition	U
4-4e	MDF	U/UN/E
4-4f	Maximum Pump Thrust	U/UN/E
4-4g	Maintenance Condition	UN
4-4j	Pumping Station Inundated	E
4-4k	Coincident Pool + OBE	UN
4-4l	Coincident Pool + MDE	E

h. Pumping stations - basic loading conditions. The loading conditions listed in Table B-17 and described below should not be regarded as a comprehensive list. In many instances, unique, site- specific factors such as water conditions, station arrangement and location, pump type and discharge arrangement, etc. will dictate modification of some of these loading conditions to fit the specific site. The conditions described should be used as a guide to the range of stability analyses required.

(1) Design loadings for stability - pumping stations.

(a) Loading Condition 4-4a - Construction Condition.

- Pumping station complete with and without backfill in place.
- No water loads.

(b) Loading Condition 4-4b - Normal Operating Condition.

- Plant operating to discharge routine local floods over a range of exterior flood levels with a maximum 2-year return period.

(c) Loading Condition 4-4e - MDF.

- Maximum water level outside protection line.
- Minimum pumping level inside.

(d) Loading Condition 4-4f - Maximum Pump Thrust.

- Maximum operating floods both inside and outside protection line.
- Maximum pump thrust.

(e) Loading Condition 4-4g - Maintenance Conditions.

- Maximum design water level inside.
- One, more, or all intake bays unwatered.

(f) Loading Condition 4-4j - Pumping Station Inundated.

- Maximum flood levels inside and outside protection line.
- Pumping station inoperative.
- Foundation drains inoperative.
- Protection line intact.

(g) Loading Condition 4-4k - Coincident Pool + OBE.

- Coincident pool
- OBE in most critical direction.

(h) Loading Condition 4-4l- Coincident Pool + MDE.

- Coincident pool
- MDE in most critical direction.

Table B-18 Concrete-Lined Flood-Control Channels
Structure Type: Retaining Wall and U-frame Structures EM 1110-2-2007

Load Case	Loading Description	Classification
1	Construction Condition	UN
2	Design Flood Loading	U/UN/E
3	Drawdown Loading	U
4a	Normal Operating + OBE	UN
4b	Normal Operating + MDE	E

i. Concrete-lined flood-control channels - basic loading conditions.

(1) Loading Condition 1 - Construction Condition (Table B-18)

- Structure complete and backfill in place.
- Channel empty.
- Construction surcharge loadings.

(2) Loading Condition 2 - Design flood loading.

- Structure complete and backfill in place.
- Water level at maximum design flood level.
- Backfill saturated to low groundwater level, adjusted to reflect the design effectiveness of the drainage system.

(3) Loading Condition 3 - Drawdown Loading.

- Structure complete and backfill in place.
- Channel empty.
- Hydrostatic pressures reflecting the highest groundwater level, adjusted to reflect the design effectiveness of the drainage system.

(4) Loading Condition 4a - Normal Operating + OBE

- Structure and backfill in place.
- Channel at mean annual operating water level.
- Backfill saturated to normal groundwater level, adjusted to reflect the design effectiveness of the drainage system.
- OBE loads acting in most critical direction.

(5) Loading Condition 4b - Normal Operating + MDE.

- The same requirements for Condition 4a except for the condition of an MDE, rather than OBE, acting in the most critical direction.